CRN: 32908

School of Science, Engineering and Environment

TRIMESTER TWO EXAMINATION

PROGRAMMES:
MSc Transport Engineering & Planning

TRAFFIC ENGINEERING: ANALYSIS & ROAD SAFETY P1

Wednesday 19th May 2021 09:00 – 16:00

Instructions to Candidates

This is an online (Open Book Examination). Time allowed 7 hours (including scanning, organizing your submitted file and uploading it onto BlackBoard).

Your answer should be in One single file uploaded onto Blackboard.

There are FIVE questions in TWO sections.

You must answer **ALL** questions.

The overall mark will then be proportioned and calculated as a percentage.

All questions carry equal marks. The percentage allocation of marks within each question is as indicated.

Statistical formulae are provided with some questions.

For any missing information, make and state clearly any necessary assumptions.

SECTION A

1. Junction capacity analysis

Table 1 presents design year turning flows (peak hour, in pcus), for the three-arm junction shown in Figure 1.

Table 1 – Turning Flows (pcus/h)

	A	B	C
A	0	280	800
B	200	0	250
C	800	250	0

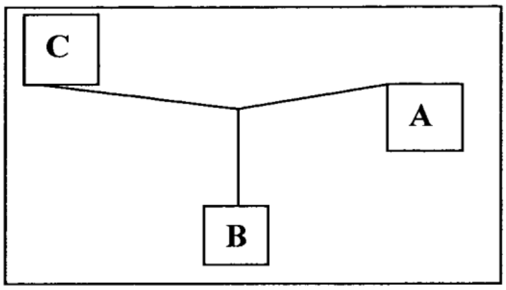

Figure 1 – Junction Schematic

Two alternative forms of control are being considered: roundabout and major-minor priority control. The geometric parameters relating to arm B are as follows:

Major-minor priority	W_{BA} , W_{BC} and W_{CB}	3.8m
	Mainline carriageway	7.3m
	Central reservation	3.6m
	Visibility distances for all turning manoeuvres	100m
Roundabout	Inscribed Circle Diameter, D	40m
	Entry radius, r	20m
	Entry width, e	6m
	Approach half-width, v	4m
	Average effective flare length, l’	15m
	Entry angle, φ	25^{o}

(a) Using the information provided in the formulae sheet in Appendix 1, calculate the estimated capacity of arm B for each design option and discuss the results. State clearly your assumptions.

(65 marks)

(b) Define the terms entry capacity and circulating flow and describe the entry capacity-circulating flow relationship which underpins the ARCADY predictive model for estimating capacity and delay at roundabouts.

(20 marks)

(c) Discuss how the effective application of signing and lane markings can help to optimise throughput and safety at a roundabout.

(15 marks)

Appendix 1 Formulae sheet for use with question 1.

Priority Intersection Design

$q^s_{BA} = X_1 \{627 + 14W_{CR} - Y (0.364q_{AC} + 0.144q_{AB} + 0.229q_{CA} + 0.520q_{CB})\}$

$q^s_{BC} = X_2 \{745 - Y (0.364q_{AC} + 0.144q_{AB})\}$

$q^s_{CB} = X_3 \{745 - 0.364Y (q_{AC} + q_{AB})\}$

$Y = (1 - 0.0345W)$

X_1 to X_3 are stream specific, namely:

$X_1 = \{1 + 0.094 (W_{BA} - 3.65)\}\{1 + 0.0009(V_{Rba} - 120)\}\{1 + 0.0006(V_{Lba} - 150)\}$

$X_2 = \{1 + 0.094 (W_{BC} - 3.65)\}\{1 + 0.0009(V_{Rbc} - 120)\}$

$X_3 = \{1 + 0.094 (W_{CB} - 3.65)\}\{1 + 0.0009(V_{Rcb} - 120)\}$

Where:

Where:	q^s_{BA}	=	capacity of movement BA (PCUs/h), etc.
	W_{BA}	=	lane width for movement BA (m), etc.
	V_{Rba}, V_{Lba}	=	right & left visibility distances (m) for movement BA, etc.
	W	=	main road width (m).
	W_{CR}	=	central reservation width (m).
	q_{AC}	=	design flow for movement AC (PCUs/h), etc.

Prediction of stream capacities for roundabout intersection

$Q_E = k (F - f_cQ_c)$ when f_cQ_c is less than or equal to F

$= 0$ when f_cQ_c is greater than F.

Where

Q_E	=	Entry flow in pcu/hour (1 HGV = 2 pcu)
Q_c	=	Circulating flow across the entry in pcu/hour
k	=	$1 - 0.00347 (\phi - 30) - 0.978 \{(1/r) - 0.05\}$
F	=	$303x_2$
f_c	=	$0.210t_D (1 + 0.2x_2)$
t_D	=	$1 + 0.5 / (1+M)$
M	=	$\exp \{(D-60)/10\}$
x_2	=	$v + (e-v) / (1+2s)$
S	=	$1.6 (e-v) / l^1$

2. Traffic signals

a) A traffic signal design is being considered for an isolated 3 arm T-junction serving arms A, B and C (labelled clockwise) with B as the minor arm. B is one-way into the junction, with one lane serving each direction. A and C also have one lane on each approach arm. Traffic flows are as shown in Table 2.

Table 2: Design hour traffic flows (pcus/h)

Traffic stream	Demand flows
A – C	800
C – A	700
B – A	350
B - C	300

Given that:

All lane widths	3.2m
The radius of turn for left turning traffic from arm B	12m
The radius of turn for right turning traffic from arm B	20m
There is an uphill gradient from B	2%
The main road A to C is level	0%
All intergreens	5 seconds

A simple two stage arrangements is proposed (main road approaches followed by side road approaches).

i) Estimate the saturation flows for the three approaches.
(use the formula: $S_0 = 2080 – 42d_G G + 100 (w_l – 3.25)$
$S_1 = (S_0 – 140d_n) / (1 + (1.5f/r))$
with the standard notation).

(15marks)

ii) Calculate the optimal green times for minimum overall delay at the junction.

(25marks)

b) It has been decided that the simple two-stage arrangement in part (a) does not provide sufficiently for pedestrians. In order to address this, two options for providing for pedestrians at this junction are being considered:

Option 1: Including an all-red stage of 12 seconds to allow pedestrians to cross while all traffic is held at red.

Option 2: Amending the layout of approach arm B to include a splitter island, so that pedestrians can 'walk -with-traffic' in two stages to cross the junction.

i) Assuming that the optimum cycle time for minimum delay is selected for each case and that optimal signal timings for minimum delay are used, estimate and compare the predicted delays to traffic from arm B to A for these two cases.

(Delay is estimated by the following formula, with the usual notation:

$$d = \left(c(1-\lambda)^2 / 2(1 - \lambda x) \right) + \left(x^2 / 2q\,(1 - x) \right) - 0.65\,(c / q^2)^{1/3}\, x^{(2 + 5\lambda)} \Big)$$

(35marks)

ii) Explain and comment on these two options, with the aid of diagrams where appropriate. Include reference to the factors which affect the safety of pedestrians at traffic signals.

(25 marks)

3. Traffic flow theory (speed/flow/density relationship)

a) Define the term "Traffic Flow Theory" and summarise the reasons behind the need for traffic engineers to understand and study this theory.

(25 marks)

b) The following equations describe the relationship between space mean speed and density for a certain set of data taken from one of the lanes for an urban motorway:

$V = 97.4 - 1.32\,K$ for $K \leq 35$ .... equation 1

$V = 75.0 - 0.68\,K$ for $K > 35$ .... equation 2

where

V is space mean speed in km/h
K is density in veh/km.

Calculate the following:

free speed,	***(10 marks)***
optimum speed,	***(15 marks)***
optimum density,	***(15 marks)***
optimum flow,	***(15 marks)***
jam density,	***(10 marks)***
average distance headways at jam density, and	
average time headways at capacity.	***(10 marks)***

(Total 75 marks)

4. Traffic flow theory (queuing theory/car following models)

a)

i) With the aid of a sketch, show how wave speeds are estimated for both stable and unstable conditions and indicate (on the sketch) the estimated wave speed at capacity.

(15 marks)

ii) Briefly describe how traffic shockwaves are formed, illustrated by an example from a motorway section.

(10 marks)

b) For a busy shopping centre, the entrance to its multi-storey car park is served by two approaches. The peak hour arrival rate at the car park is 250 cars per hour and the service rate at each entrance barrier to the car park is three cars per minute. Assuming that arrivals are divided equally between approaches, estimate the average queue size and average waiting time in the system (including cars being served). Briefly comment on the results.

Use the following equations in estimating the average queue size and average waiting time:

Average queue size = $\lambda / (\mu - \lambda)$

Average waiting time = $1 / (\mu - \lambda)$

where

λ is the mean rate of arrival

μ is the mean rate of service

(25 marks)

c) In estimating the minimum stopping distance, the Highway Code states that "… a two second time gap may be sufficient…". Using this rule, (i.e. the "two second rule") and what is known as the "California Code" (i.e. drivers allow one car length for every v mph speed), derive the relationships that describe these two theoretical models and discuss the differences between them.

(50 marks)

SECTION B

5. Road safety

a) In the context of road safety studies, explain and discuss the terms exposure, risk and injury consequences and illustrate their importance by reference to the case of pedal cyclist casualties.

(25 marks)

b) Briefly summarise and review the key elements of the Vision Zero traffic safety policy, developed in Sweden in the late 1990s.

(25 marks)

c) With reference to Reported Road Casualties in Great Britain: Main Results 2019 (Department for Transport), discuss recent trends in casualty numbers in Great Britain and review the possible reasons for changes in the numbers compared to the recent past.

(50 marks)